Design and preliminary evaluation of a soil resistance sensor for soil compaction sensing in viticulture

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Introduction

Soil compaction is one of the influential soil characteristics that, if present, may hinder the growth of crop roots and reduce water infiltration into the soil resulting in lower crop yields (Adamchuk and Christenson, 2007). Some practices usually adopted in vineyards management, such us intense tractor traffic along fixed paths and maintenance of permanent grassing of the vineyard for pesticide distribution, were favouring soil compaction. Moreover, the tractor traffic together the soil management has directly effects on runoff and water erosion (Biddoccu, 2017).
In the calendar of agricultural activities for vineyards farm, the crop protection stage constitute the most responsible of soil compaction because the frequent transit of sprayer machine characterized by high specific pressure the ground.
Direct measurement of soil compaction, such as the determination of dry soil bulk density, dry bulk specific volume, void ratio, and porosity are time consuming (Johnson and Bailey, 2002). Soil mechanical resistance, defined as the resistance to the movement of plant roots or tillage tools through the soil, is directly related to soil strength. Therefore, a cone penetrometer used to measure the force required to vertically insert a conical tip into the soil has become the standard practical mean for assessing the degree and variability of soil compaction (ASAE Standard, 2016).
The objective of this study was to develop a new instrument to measure the soil mechanical resistance, called "dynamometric knife", that can measure georeferenced data of soil compaction in a continuous way. Preliminary field tests by using the dynamometric knife were assessed in different vineyard soil conditions.

Materials and methods

The dynamometric knife was composed mainly by a steel pivoted knife connected to a load cell. The measurement principle was based on first-oder lever. This allow achieving the load force (N) necessary to perform a cut at specific deep. Then, this data was related to the contact surface between knife and soil in order to get the specific pressure (MPa). The instrument can be coupled with a standard three-hitch point, and is adjustable for acquiring data at a depth ranging from 0 to 0.4 m. A data acquisition system made of

signal sensor processor and a software allows collecting the force required to cut the soil at the pre-established depth, and the relative geographical position in real-time (Fig. 1). Preliminary field test were assessed to measure the soil mechanical resistance in different soil management vineyards. The dynamometric knife was used in a permanent grassing vineyard and in a tilled one, both in the tractor traffic paths and in the central area among the traffic paths (Fig. 2). Measurements were also taken in a high density vineyard were the soil management consisted in annually sub-soiling tillage in alternate rows (Fig.3). Data collected were modelled in a mixed linear regression model by using the extension package lmerTest (Kuznetsova et al., 2014) of the R statistical software (R Core Team, 2013).

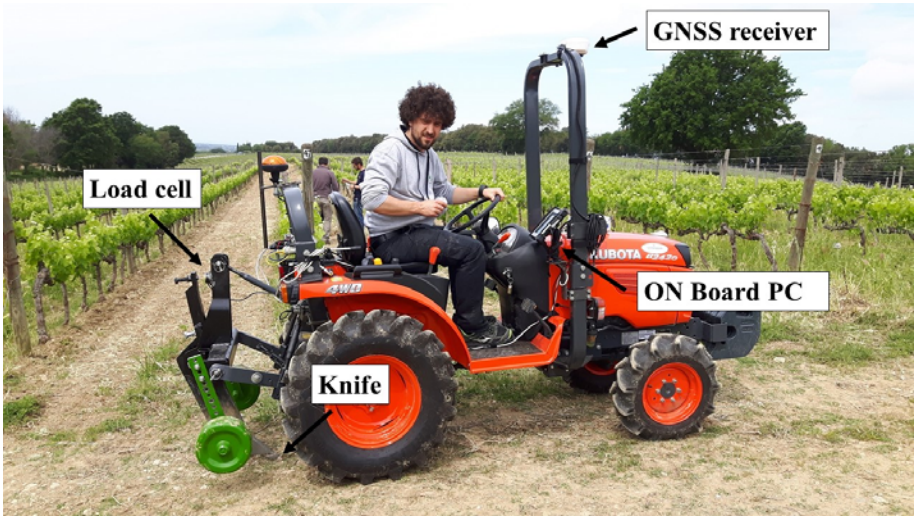

Figure 1 Dynamometric knife mounted on the mobile tractor field laboratory

Figure 2 Measurement of soil mechanical resistance in the middle of the row and along the traffic path.

Figure 3 On the go measurements in high-density vineyard.

Results

The preliminary results showed that the dynamometric knife works properly and allows an instantaneous overview of soil mechanical resistance measurements. Nevertheless further improvements are required to enhance its precision and versatility.
Analysis of data showed that the force needed to cut the soil within the tractor traffic paths was always statistically higher compared with the force needed in the central area among the traffic paths, both in permanent grassing that in tilled vineyard. Same results of higher force required were obtained when the no-till soil was compared with the soil tilled the previous year.
Further studies are necessary to investigate the performance of dynamometric knife in relation with the data collected with the cone penetrometer and measures of bulk density, in order to establish a relation between soil compaction data obtained with different instruments.

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